Internal Combustion Engine Research at Argonne National Laboratory

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California Advanced Reciprocating Internal Combustion Engine Collaborative Workshop
Sacramento, CA
July 10, 2001

Presentation Outline

- Introducing Argonne
- Active engine research programs
- Industrial cogeneration program
- Research on large-bore diesel engine
  - Simultaneous reduction of NOx and PM
  - Evaluation of NOx Catalyst
- Other supporting technologies
- Argonne technologies for ARICE program

Argonne Is One of DOE's Largest Research Facilities

- The first national laboratory, chartered in 1946
- Operated by the University of Chicago for the U.S. Department of Energy
- Major research missions include basic science, environmental management, and advanced energy technologies
- About 4,500 employees, including about 1,775 scientists and engineers, of whom 800 hold doctorate degrees
- Since 1990, Argonne has worked with more than 600 companies and numerous federal agencies.

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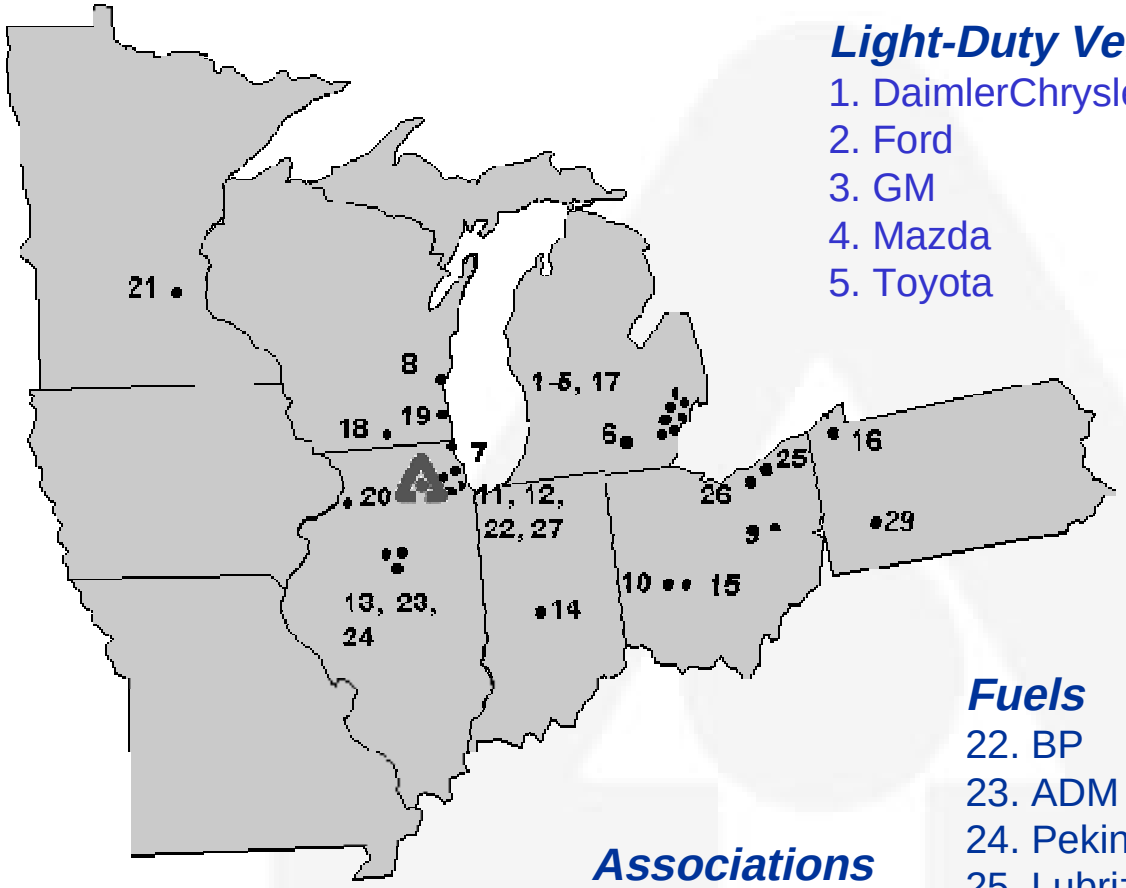
Argonne Is Ideally Located in the Heartland of the U.S. Engine Manufacturing Industry



Light-Duty Vehicles and Engines

1. DaimlerChrysler
2. Ford
3. GM
4. Mazda
5. Toyota
6. Nissan
7. Outboard Marine
8. Harley-Davidson
9. Hercules
10. Honda

Heavy-Duty Engines

11. Navistar
12. EMD
13. Caterpillar
14. Cummins
15. Cooper
16. GE
17. DDC
18. Fairbanks-Morse
19. Waukesha
20. Deere
21. ONAN

Fuels

22. BP
23. ADM
24. Pekin
25. Lubrizol
26. BP

Associations

27. EMA
28. SAE

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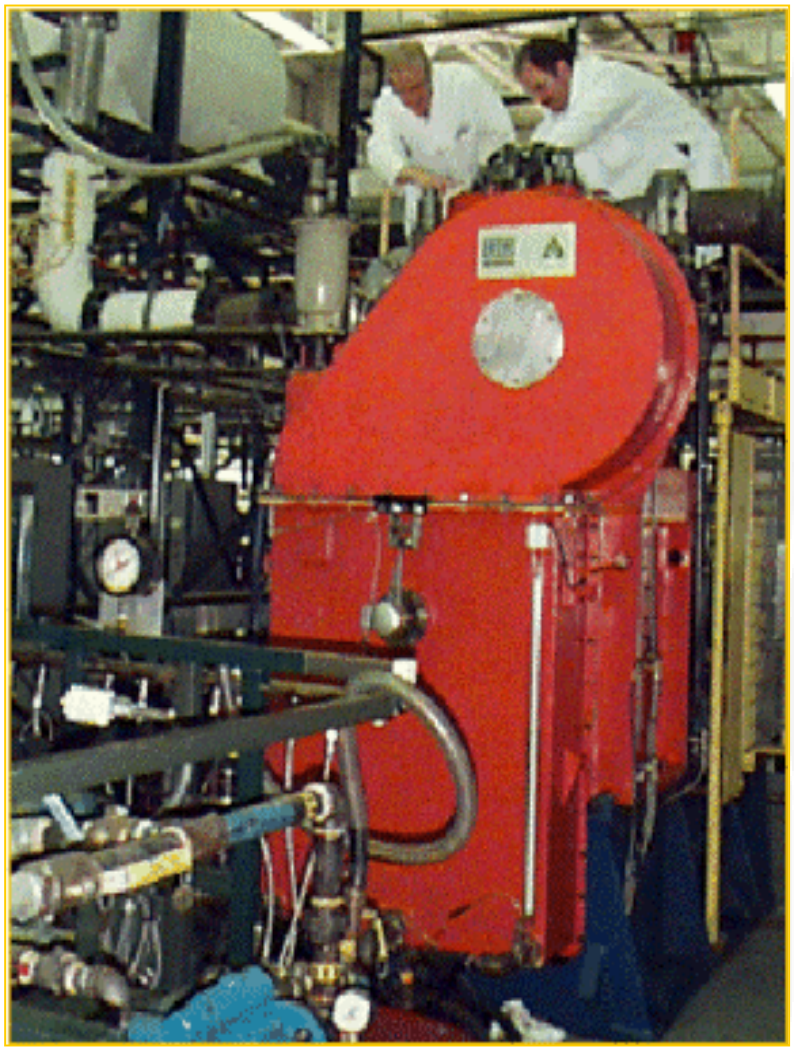
Engine Research Has a Focused Mission

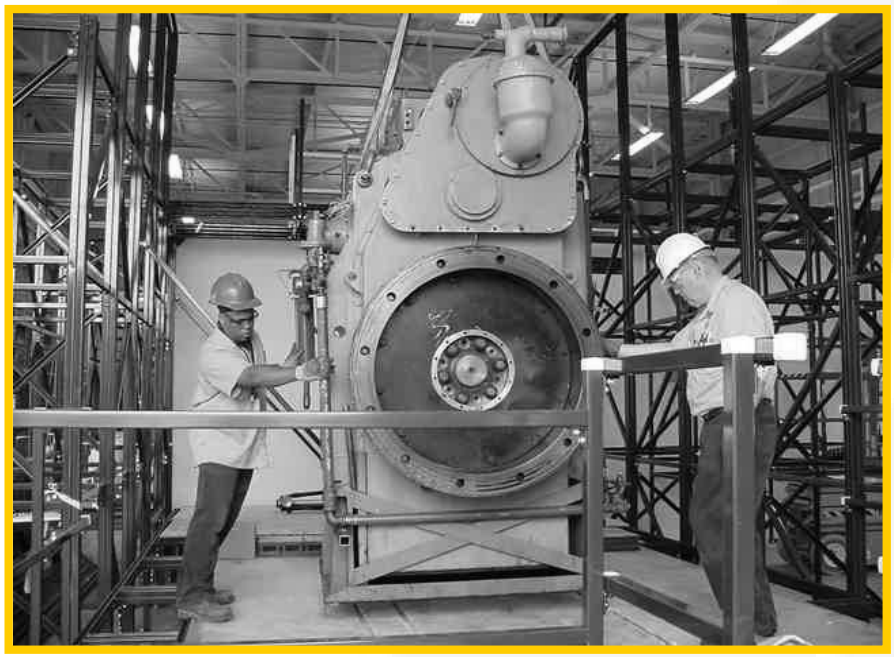
- Develop advanced technologies
  - Improve engine fuel consumption
  - Reduce engine-out and tailpipe emissions
  - Improve durability by using advanced materials
- Develop experimental and analytical capabilities
  - Assist engine manufacturers in design decisions
  - Prove the viability of new technologies
- Assist in directing DOE and industry research
  - Industry tech team meetings
  - DOE reviews
  - Professional society meetings

Integrated Research Facility Tests Engines of Automobile to Locomotive Size



- **Researchers can**
  - Analyze basic design
  - Improve performance and reliability
  - Increase fuel efficiency
  - Reduce exhaust emissions
- **GM's ElectroMotive Division**
  - Major investment at Argonne
  - Interest sparked by Argonne emission control technology
  - Continuing to expand

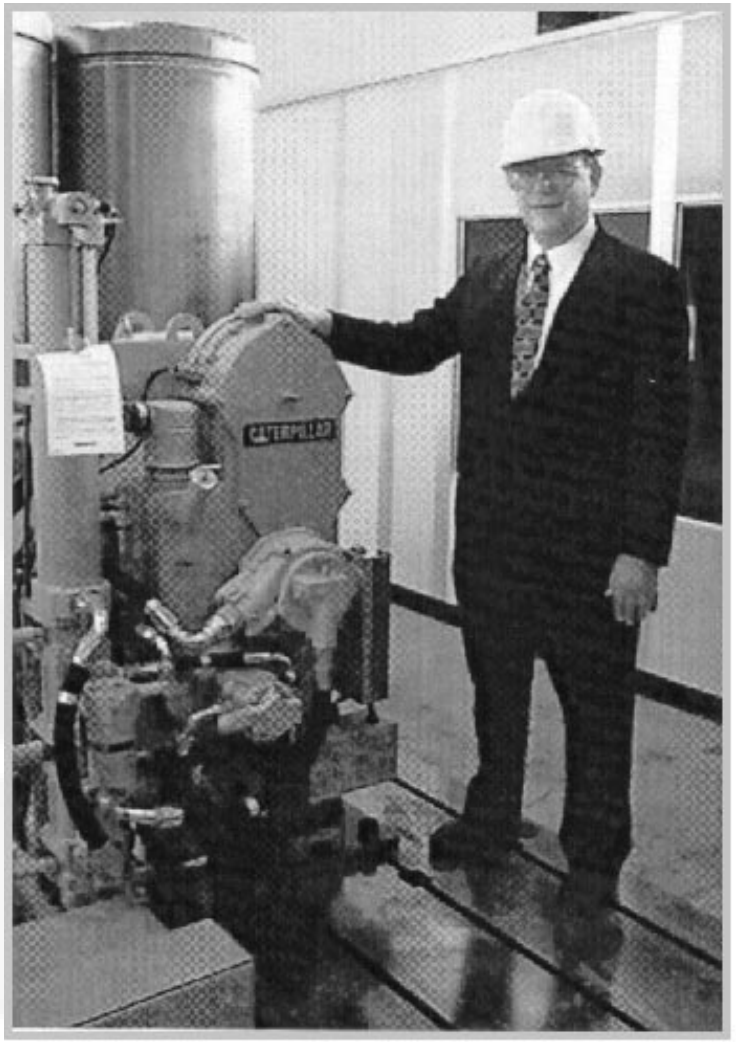
Second Large-Bore Research Engine Being Installed



- Primary objective is in-cylinder emissions control research
- Includes NOx catalyst evaluation
- Operational in September 2001
- Supported by GM-EMD

Dedicated Test Cell Available for Heavy-Duty Truck Engine Research

- Part of the integrated test facility
- Latest performance and emissions instrumentation
- Advanced in-cylinder emissions control concepts being evaluated
- Cooperative Research and Development Project
- Funded by DOE's Office of Heavy Vehicle Technologies and Caterpillar



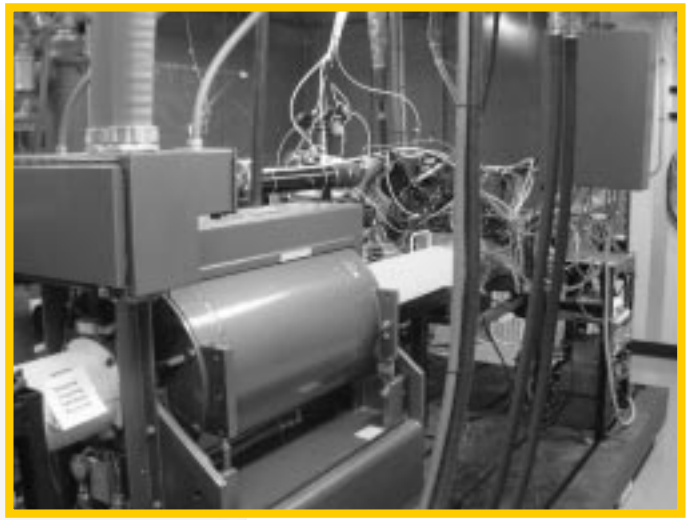
Argonne Is Developing Advanced Technologies to Reduce Emissions

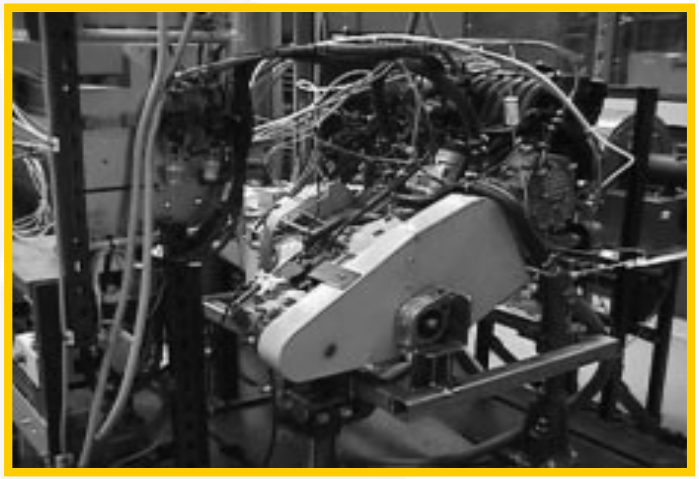
Argonne's Diesel Program is:

- Systems-driven
- Barrier-focused

Argonne's approach:

- In-cylinder emissions control technologies
- Fuel systems and controls, including spray research
- Real-time, transient emissions measurements





Mercedes 1.7-Liter Diesel Engine

Industrial Cogeneration Research Continued for 12 years

- Oxygen-enriched diesel engine research
  - Computer simulation studies
  - Technical and economic evaluations
  - Experiments for cogeneration applications
- Thermal degradation of organic Rankine cycle fluids
- Investigation of direct wood combustion
- Coal-water slurry diesel injection systems research
- Economic studies of distributed electric power generation

Control of Engine-Out Emissions by Selectively Modifying Intake Air

1999 R&D 100 Award

- In-cylinder combustion control complements aftertreatment and fuel modifications
- Membrane separates air into oxygen-rich and nitrogen-rich streams for use in engine

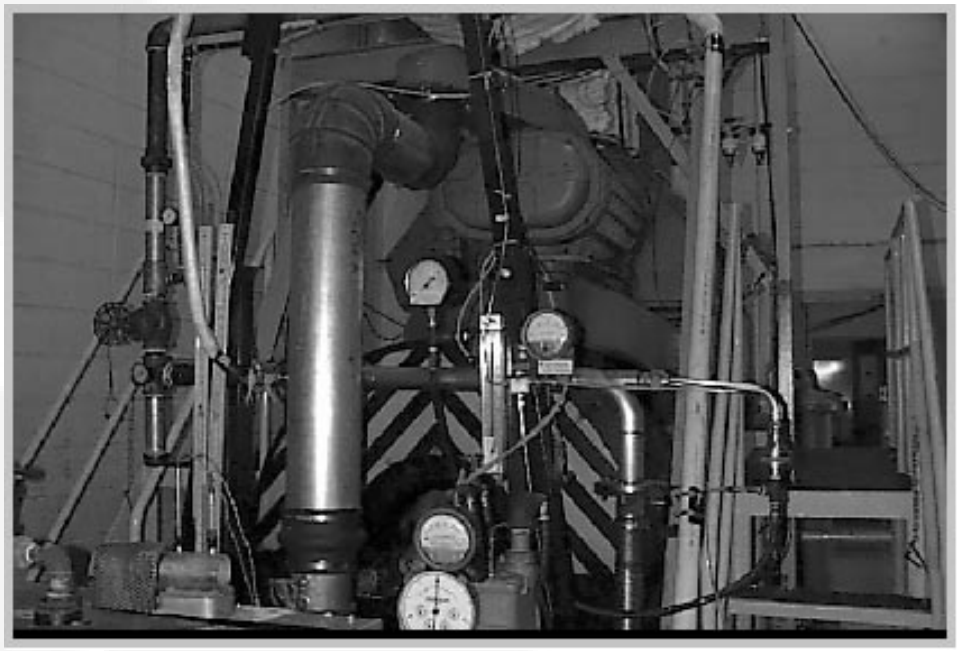
Argonne has a half-dozen patents on engine air composition

Unique engine research has directly led to industrial collaboration

- GM ElectroMotive Division
- Caterpillar
- Degussa

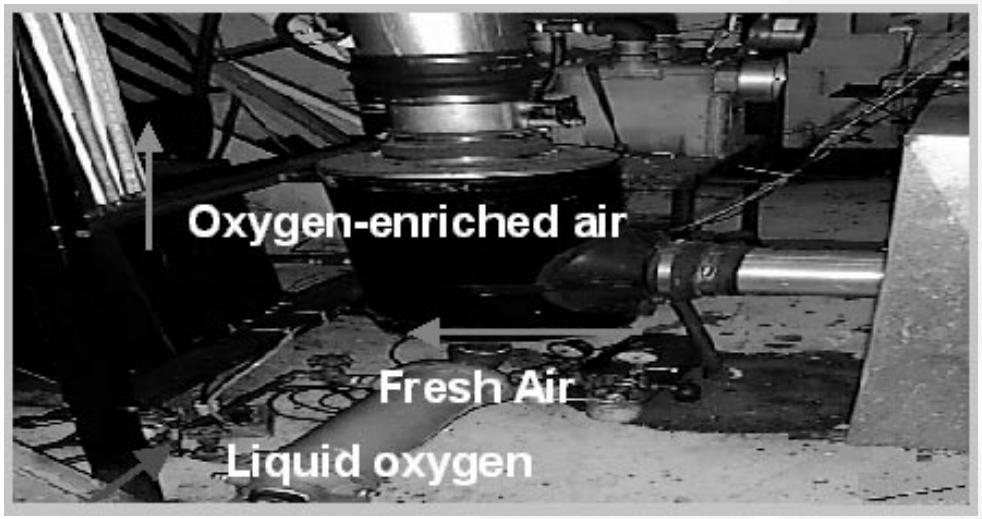
Oxygen-Enriched Intake Air Lowers Locomotive Emissions

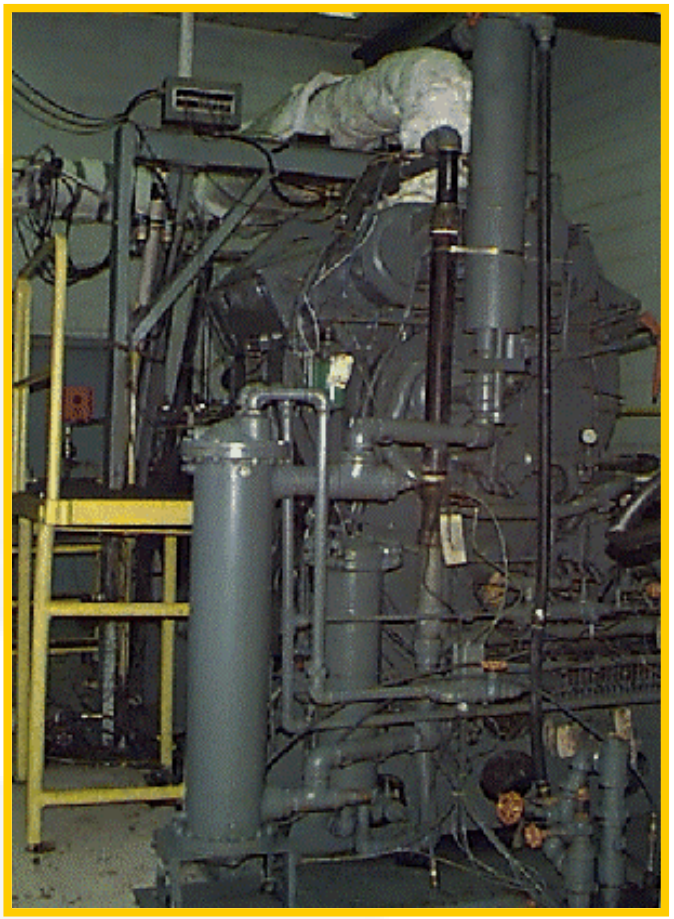
- Need to “think out of the box”
- Extensive analytical study preceded engine experiments
- Extensive experimental data obtained with and without NOx reduction catalyst
- Supported by DOE/SC-LTR
- CRADA Partners
  - Association of American Railroads
  - GM-EMD



EMD 2-Cylinder 567-B Research Engine

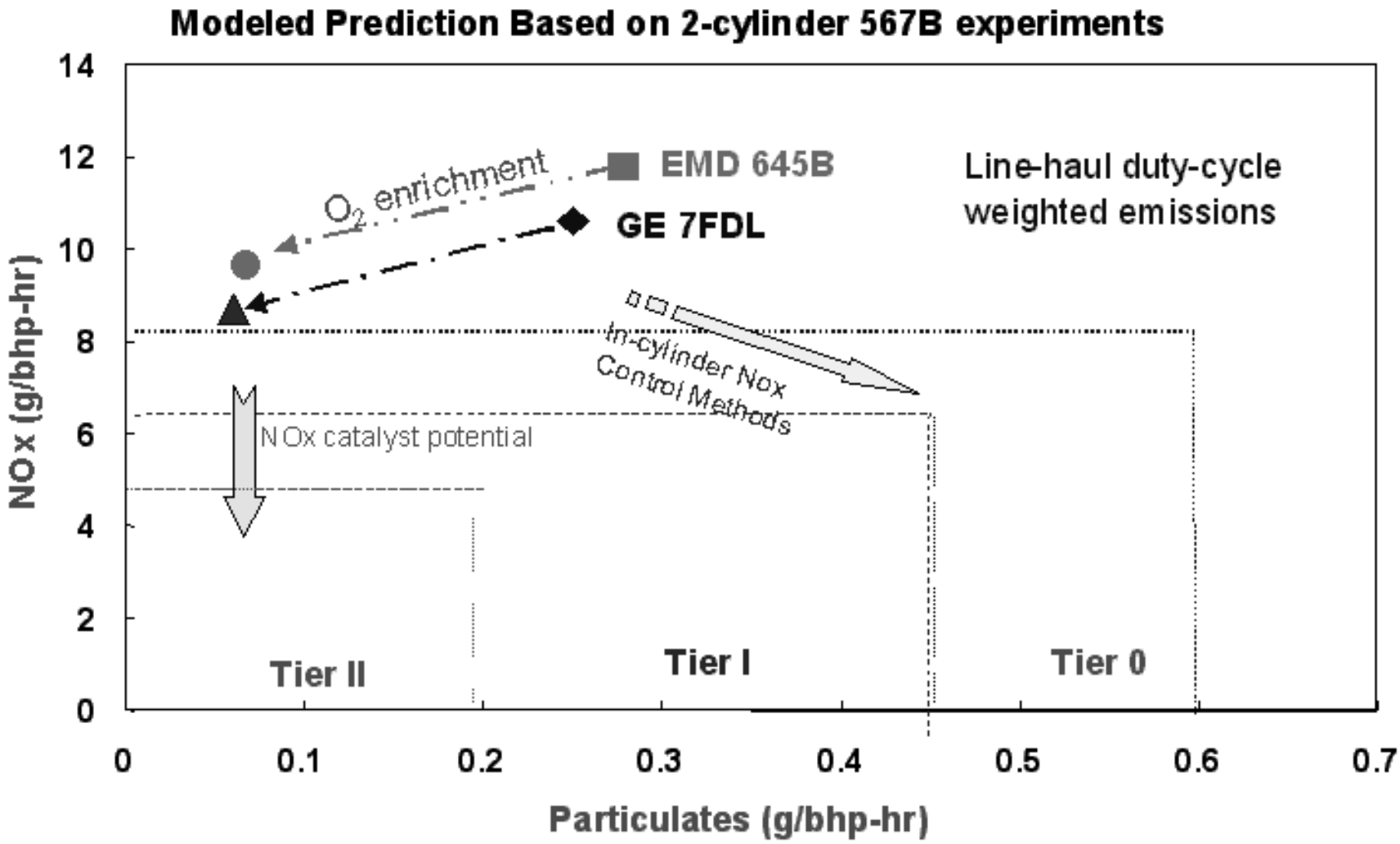
Potential for Simultaneous Reduction of NO_x AND Particulates





Intake Air Oxygen-Enrichment System

O2 Enrichment Provides Innovative Path to Meet Emissions Standards



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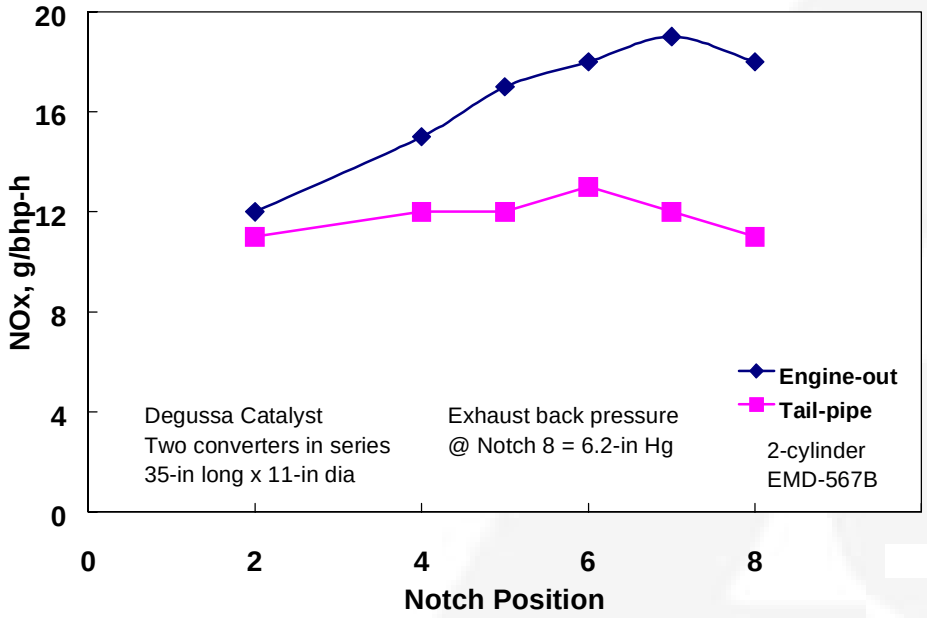
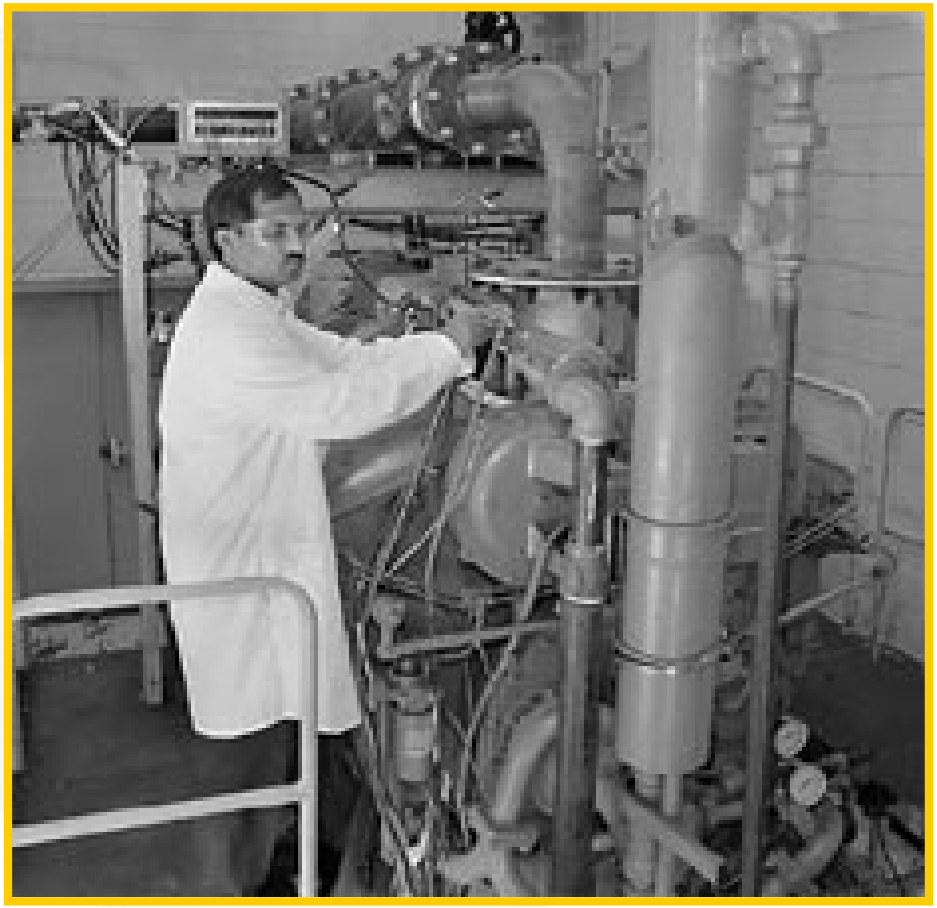
Degussa Catalyst Demonstrates 35% Reduction in NOx





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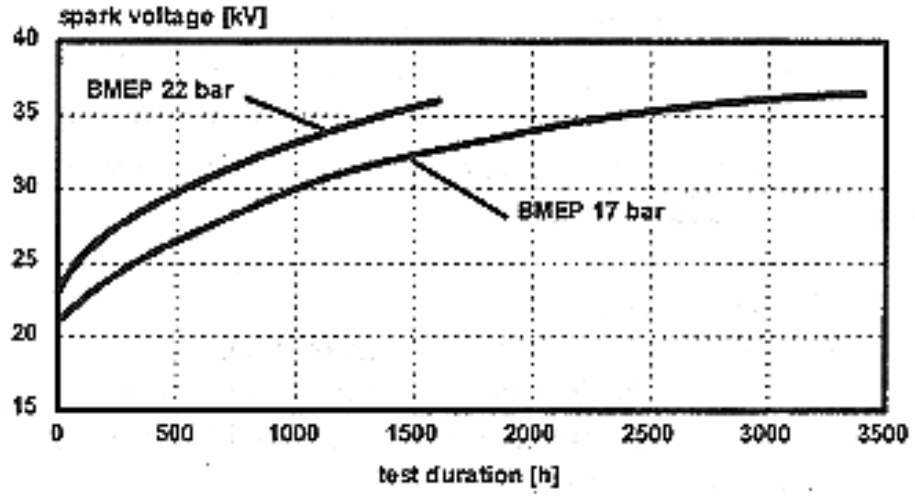
Technology Wins R&D 100 Award

- Argonne patented “Clean Diesel” technology
- Reduces NOx and particulate emissions simultaneously

Energy Secretary Richardson:

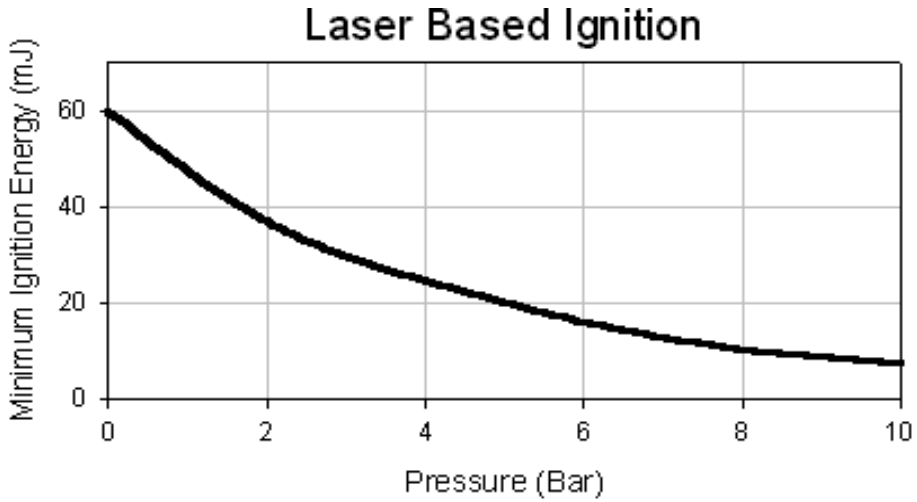
“...program is a model for industry/DOE collaboration.”

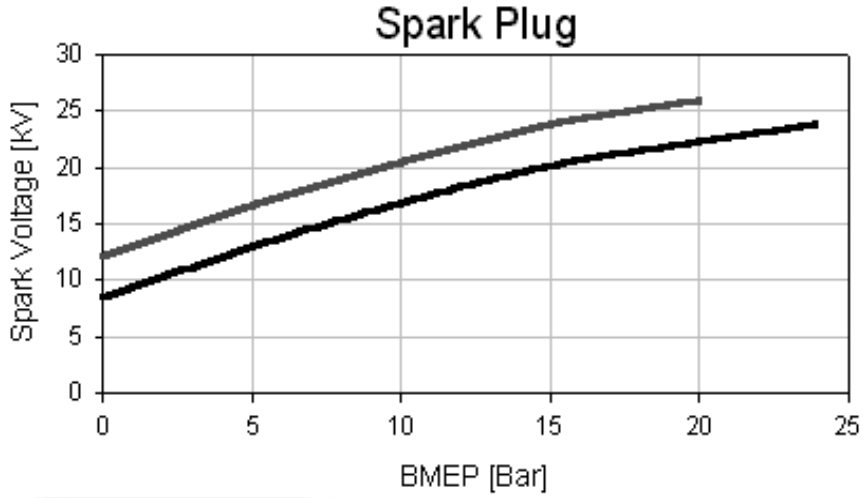
Spark Plug Durability Is a Concern for Current Natural Gas Engines



Spark plug electrodes erode over time, and the spark gap needs frequent adjustment. For a spark plug with a 10,000-hr lifetime, the gap needs to be adjusted every 1000-4000 hrs.

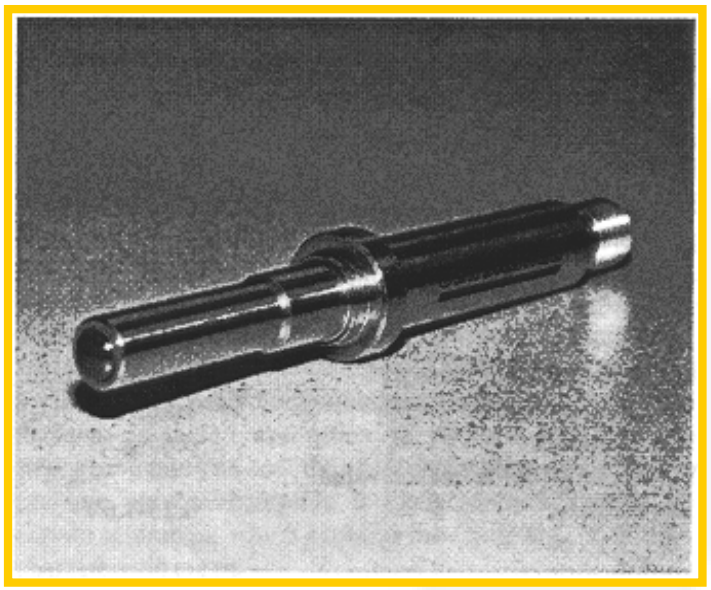
Laser-Based Ignition Could Solve a Major Problem with Natural Gas Engines



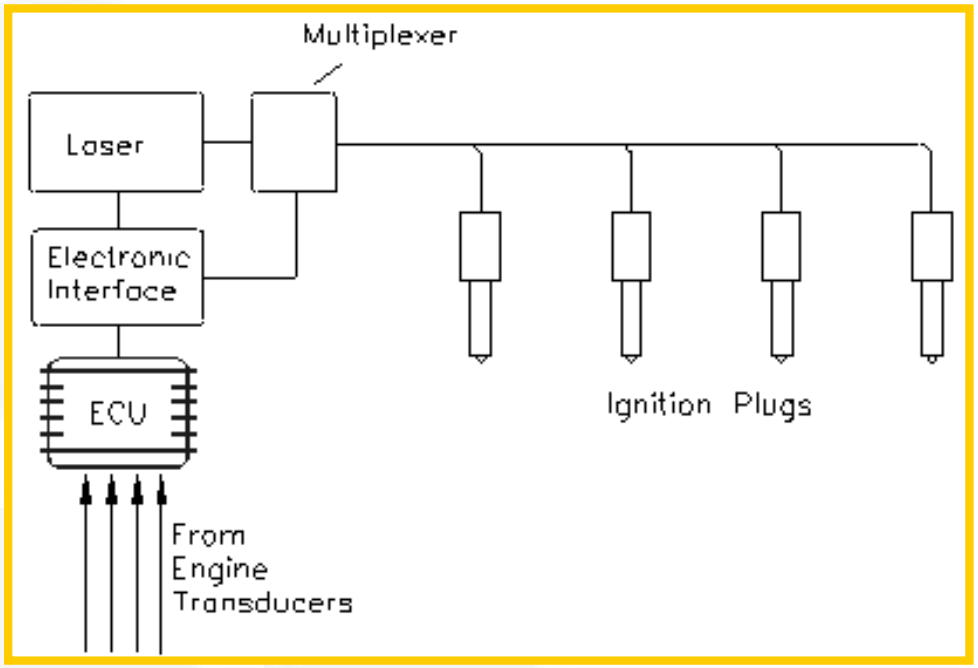


- Minimum ignition energy decreases with increase in pressure.
- The ignition point is away from the walls.
  - Less heat loss to walls enhances overall efficiency.
  - Centrally located ignition kernel results in uniform burning of fuel/air mixture, which could result in lower emissions.
- Ignition kernel surface area can be tailored by optics to extend operation into extremely lean fuel air mixtures.

Argonne Development Can Increase Efficiency and Lower Emissions



Prototype Laser Ignition Plug



Prototype Laser Ignition System

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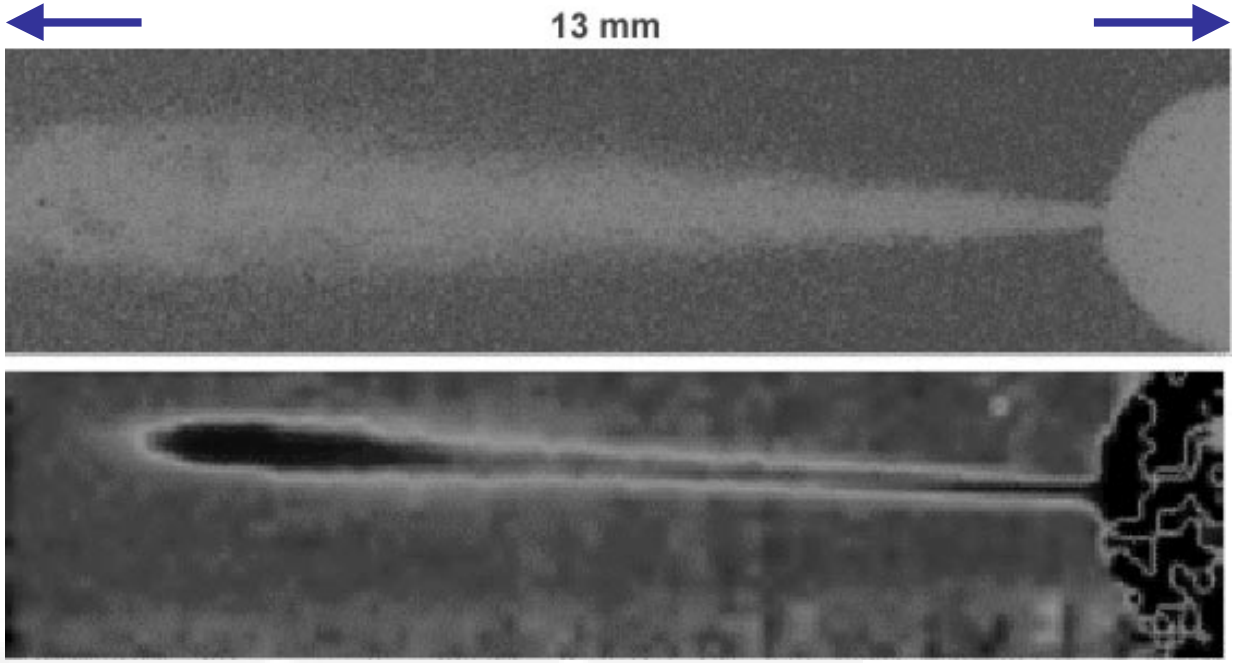
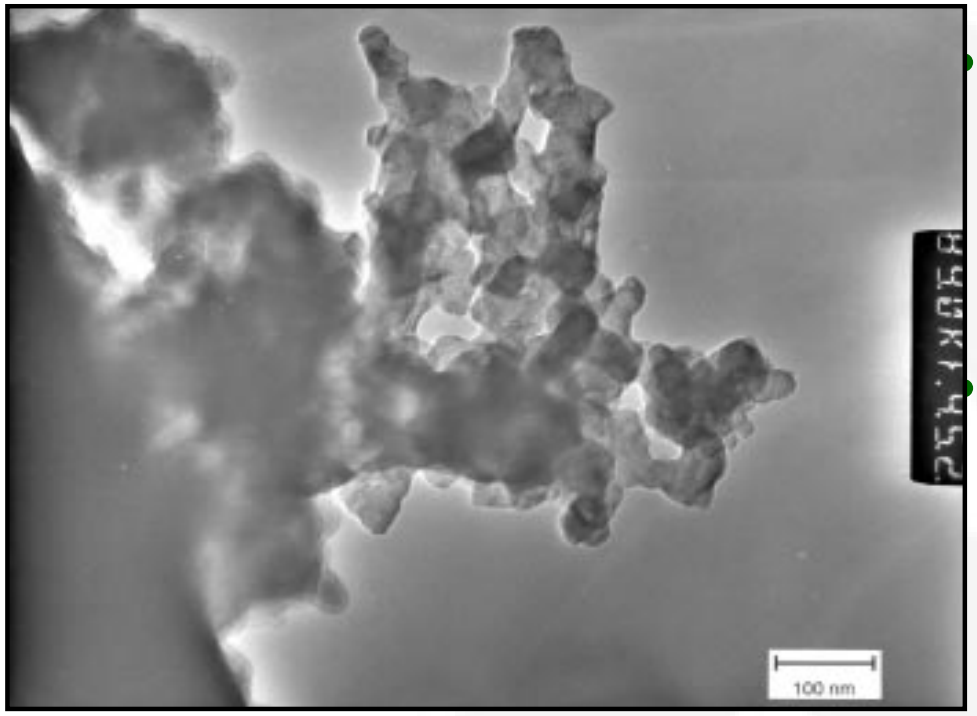
X-Rays Open a New Paradigm in Engine Research



- X-rays penetrate the mist surrounding the spray core and reveal a more realistic image of the spray plume structure.
- More than 99% of the fuel mass is concentrated in the spray core, which takes a volume less than 10% of that shown by visible light images.

Unique Sampling Method Used to Study Soot Morphology



Transmission Electron Microscope Photo

- Detailed morphology and chemistry of diesel particulate matter by using thermophoretic sampling
- Research Goals
  - Better understanding of diesel particulates
  - Develop efficient diesel engines and particulate reduction devices
  - Improve public health

Many Applications for Near-Frictionless Carbon Coatings

- Sliding/rolling/rotating components
  - Fuel injectors
  - Transmissions
  - Turbochargers, etc.
- Excellent adhesion to:
  - Metals
  - Ceramics
  - Plastics
- Industrial interest
  - 3500 inquiries
  - 80 non-disclosure agreements
  - 30 work-for-other projects
  - Commercial scale-up next objective

Argonne Technologies Could Benefit California ARICE Program

- Laser-based ignition system
  - Improves reliability and durability of the system
  - Decreases engine down time
- Engine-out emissions reduction by combustion air composition modification
- On-engine evaluation of NOx reduction catalysts
- Sensor research for NOx and particulates
- Low-friction coatings for engine components